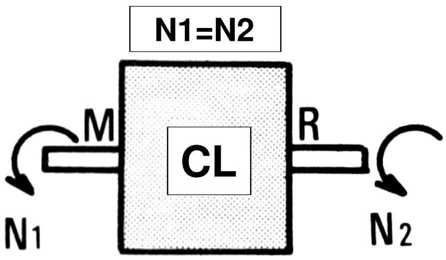
Clutches

Function of a Clutch



	Speeds	
Driving Member N1	0	1
Driven Member N2	0	0 or 1

The object of a clutch is to connect a *stationary* machine part to a *rotating* one,

The main functional difference between a *brake* and a *clutch* is that, instead of arresting motion like a brake, a clutch has to transmit motion from a power source to a stationary component until the two are moving at the same speed; that is, until there is no relative angular velocity between driving and driven parts.

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The most obvious requirement of a friction clutch is that it should be capable of

When starting a vehicle or machine from rest,

Engaging the clutch will dissipate part of the *kinetic energy*

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If the resulting temperatures are excessive a deterioration in clutch performance may occur. The following effects may be the result of high temperatures:

1. **The** *coefficient of friction*
2. **Intermediate** *plates distort*
3. **Clutch** *facings distort*
4. **The** *wear* **of the facings is**

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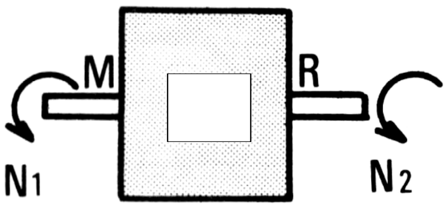
Function of a Clutch



N1=N2 : Clutch is
N2=0 : Clutch is

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TYPES OF CLUTCHES

A. POSITIVE
B. FRICTION
C. POWER CONTROLLED
D. FLUID AND POWDER

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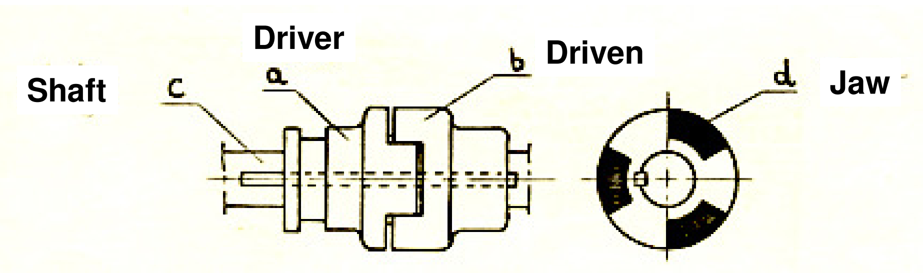
POSITIVE CLUTCHES

Jaw clutches can be with *square jaws* for driving in both directions or with *spiral jaws* for driving in one direction.



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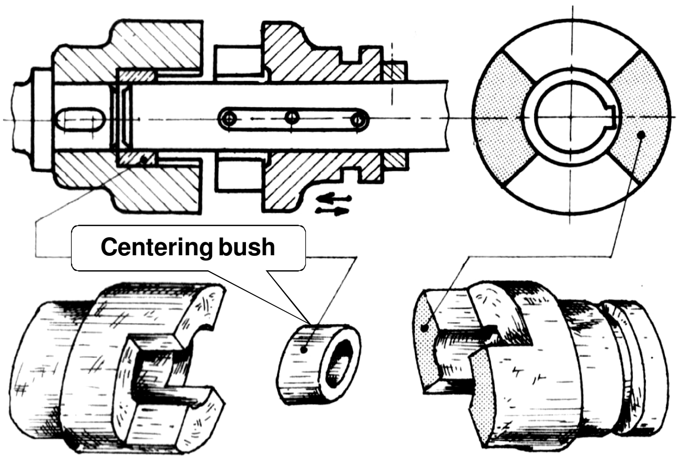
Jaw Clutch

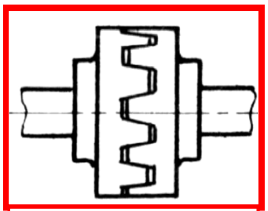


Jaw Clutch

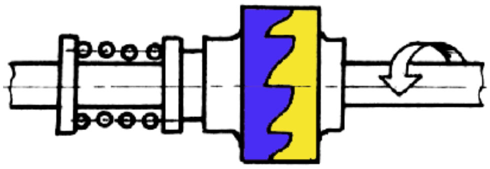
Jaw clutches can be engaged only at low speeds, below 60 rpm.

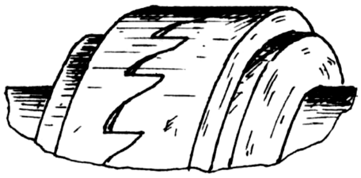
Spiral jaw clutches are to be used when engagement

Toothed Clutch



Engaged Clutch
Trapezoidal teeth





FRICTION CLUTCHES

Such clutches are used to engage smoothly two shafts in motion and release them quickly or slowly as required.

Friction clutches are classified into different types according to:

I. Geometry
II. Method

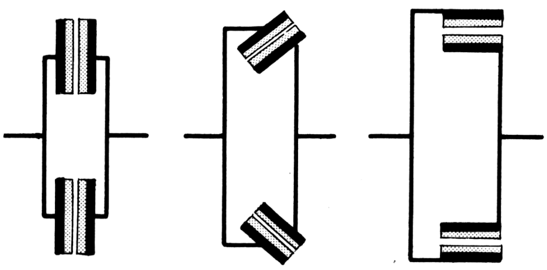
I. Geometry of friction surface:

1. Plate clutch
2. Conical clutch
3. Cylindrical clutch
4. Rim clutch
5. Roller clutch

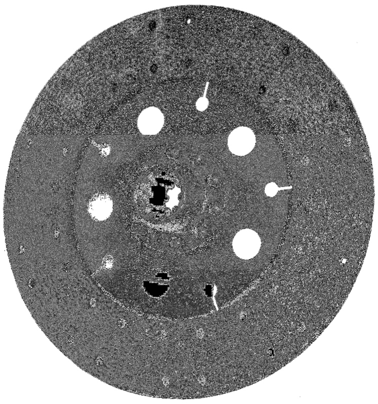
II. Method of clutch operation:

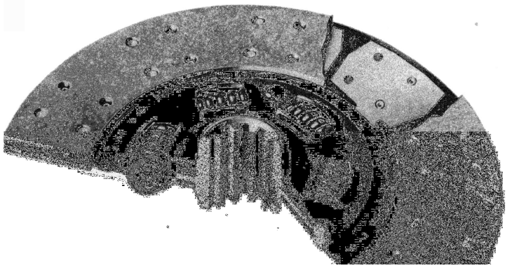
1. Mechanical
2. Electromagnetic
3. Pneumatic
4. Hydraulic

Friction Surfaces of a Clutch



Friction Plate





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The method of clutch operation

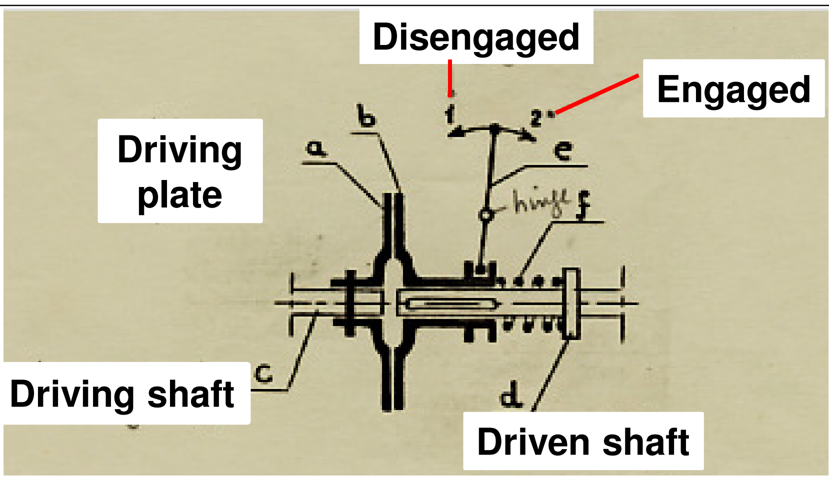

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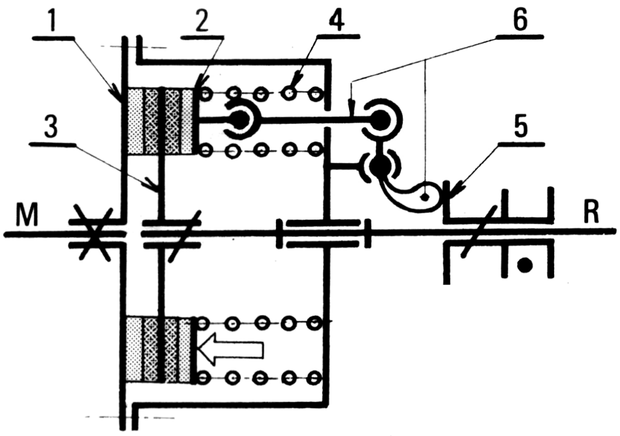
Plate Clutch



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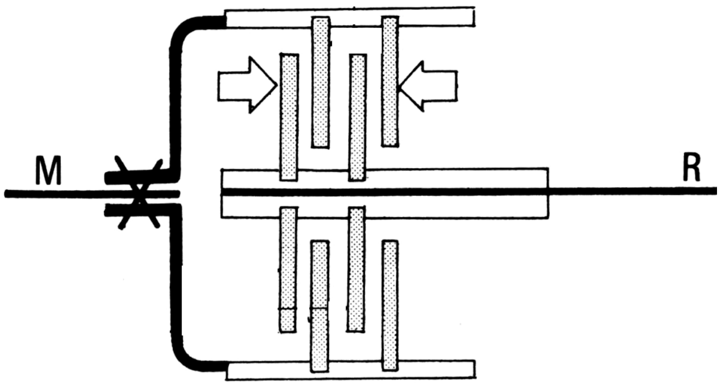
Multi-Plate Clutch



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Torque Transmission
Plate Clutch

The torque transmitted by a Plate Clutch depends upon:
.. The axial force
.. The mean
.. The coefficient

$$T = \mu \cdot F_a \cdot r_m \cdot n$$

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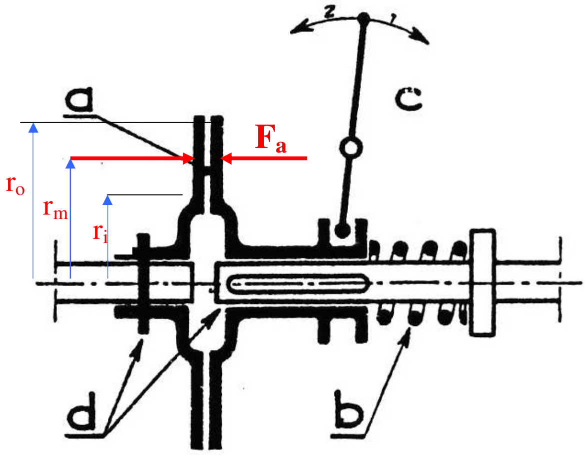
Torque Transmission
Plate Clutch



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TORQUE ANALYSIS

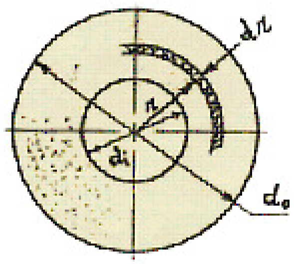
First Case: **UNIFORM PRESSURE DISTRIBUTION**

The pressure is assumed to be uniformly distributed over the friction surface.

The axial force on an annular ring of radius r and thickness dr is:

Where, p is the unit pressure

$$F_a = 2\pi p \int_{r_i}^{r_o} r\, dr$$



Friction Surface

The frictional force on the ring becomes

$$dF_f = \mu\, dF_a$$

The frictional transmitted torque is then

$$dT_f = r \cdot dF_f = 2\pi \mu p r^2 dr$$

Therefore,

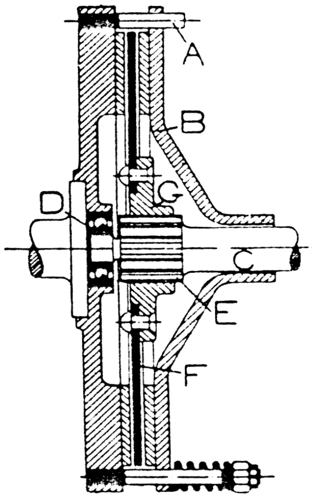
$$T_f = 2\pi \mu p \int_{r_i}^{r_o} r^2 dr = \frac{2}{3}\pi \mu p \left(r_o^3 - r_i^3\right)$$

Since $T_f = \mu F_a r_m$ for the whole plate

Therefore, $\frac{2}{3}\pi \mu p (r_o^3 - r_i^3) = \mu . \pi p (r_o^2 - r_i^2) . r_m$

From which, $r_m = \frac{2}{3}\left(\frac{r_o^3 - r_i^3}{r_o^2 - r_i^2}\right)$

Single Plate Friction Clutch



Single-plate clutch

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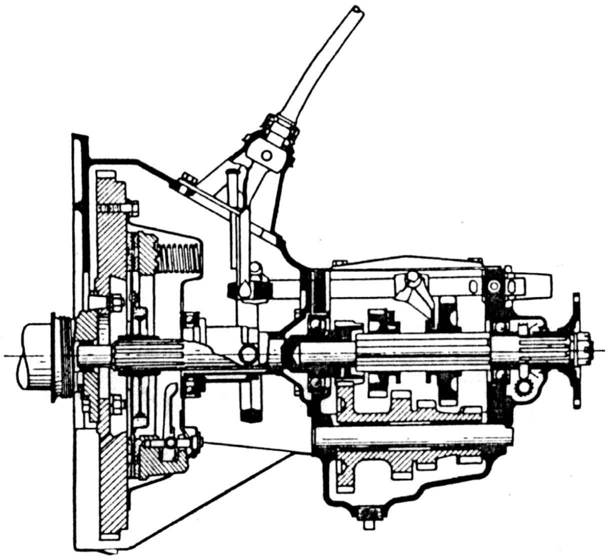
Single-Plate Friction Clutch of a Car



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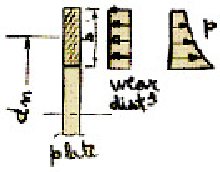
Second Case: **UNIFORM WEAR DISTRIBUTION**

The condition of uniform wear distribution is usually assumed for new contact surfaces.



Wear α

α

W = k p v , v = ω r

W = K p r

i.e. p =

As for uniform pressure $T_f = \int_{r_i}^{r_o} 2\pi\mu p \; r^2 \, dr$

$$T_f = 2\pi\mu K' \int_{r_i}^{r_o} r\,dr \longrightarrow = \pi\mu K' \left(r_o^2 - r_i^2\right)$$

As for uniform pressure $F_a = 2\int_{r_i}^{r_o} \pi \; p \; r \; dr$

$$F_a = 2\pi K' \int_{r_i}^{r_o} dr \qquad = 2\pi K' \left(r_o - r_i\right)$$

Since $T_f = \mu \, . \, F_a \, . \, r_m$

Therefore, $r_m = \frac{1}{2} . \left(r_o + r_i\right)$

$$T_{f_{UP}} = \mu . F_a . \frac{2}{3}\left(\frac{r_o^3 - r_i^3}{r_o^2 - r_i^2}\right)$$

$$T_{f_{UW}} = \mu . F_a . \frac{1}{2}\left(r_o + r_i\right)$$

Remark:

$d_m = (d_o + d_i)/2$ and $b = (d_o - d_i)/2$

$A_f = \pi \, d_m \, b$

$d_m / b = 8$ to 10 for single plate

$= 4$ to 5 for multi plate

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Materials for Contact Surfaces:

The material of a friction surface should meet the following requirements:

.. Should have

.. Should not

.. Should

.. Should resist

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Friction Linings may be:

.. A fabric woven of asbestos

.. Molded in press moulds

The friction elements of clutches that are to are made of steel with subsequent hardening i.e. the simultaneous addition of nitrogen, carbon and

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Coefficients of Friction and Allowable Pressures for Friction Surfaces of Clutches

Friction pair materials	Dry	Oily	p Kg/cm^2
Cast iron / Cast iron	0.15	0.06	2.5 – 4 6 - 8
Cast iron / Steel	0.2 …..	….. 0.06	2.5 – 4 6 - 8
Hardened steel / Hardened steel		0.08	6 - 8
Leather / CI	0.5		0.7 - 1
Asbestos fabric / Ci	0.35 – 0.45		2 - 4
Ferodo / Steel	0.3		0.7
Cork / CI	0.35		0.1
Wood / CI	0.3		1.5 – 3.5

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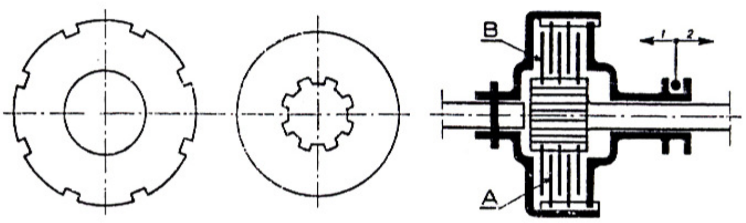
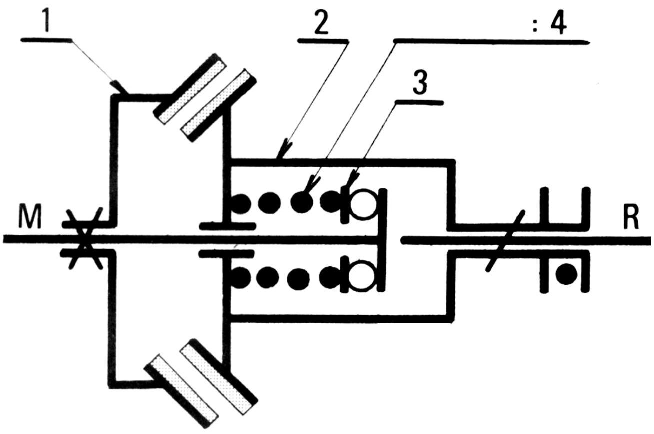
Engagement Factor: K_e

Metal machine tools	1.25 – 1.5
Automobiles	1.2 – 1.5
Tractors	2 – 2.5
Cranes	1.2

Multi-Plate Friction Clutch



Conical Clutch



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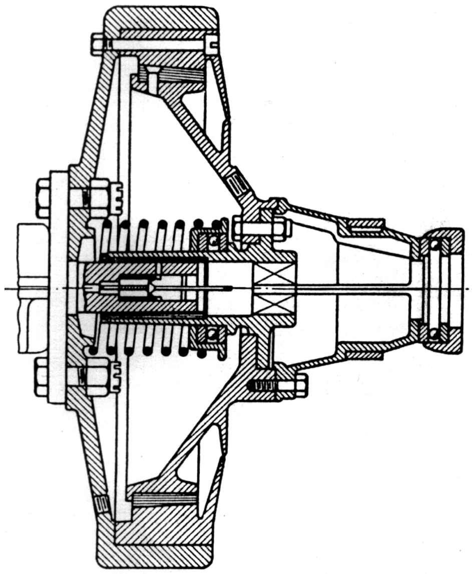
Conical Clutch



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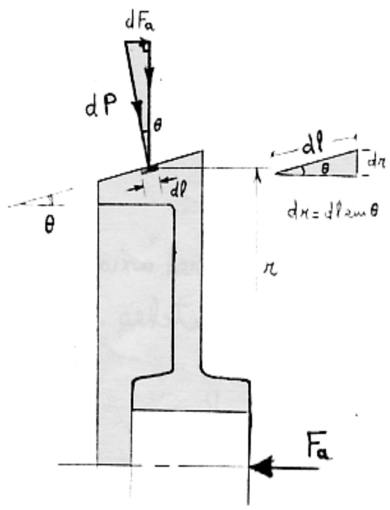
Conical Clutch

The cone clutch embodying the mechanical advantage of the wedge,

It has greater facilities for than a plate clutch of similar dimensions; hence it may be somewhat more heavily rated.

A cone clutch uses the mechanical advantage

The mechanical advantage of a wedge varies as the



Torque Analysis

$$dP = 2\pi r . p . dl$$

$$dF_a = dP . \sin\theta \qquad dr = dl . \sin\theta$$

$$= 2\pi r . p . dr$$

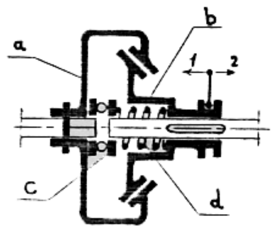
$$F_a = \int_{r_i}^{r_o} 2\pi r . p . dr$$

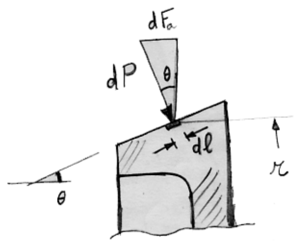
Friction force on elemental ring:

$$dF_f = \mu . dP$$

$$dT_f = r . dF_f = 2\pi\mu . p . r^2 dl$$

$$T_f = \int_{r_i}^{r_o} \frac{2\pi\mu}{\sin\theta} . p . r^2 . dr$$





UPD Case:

$$F_a = 2\pi p \int_{r_i}^{r_o} r \, dr = \pi \, p \cdot \left(r_o^2 - r_i^2 \right)$$

$$T_f = \frac{2\pi \mu \, p}{\sin\theta} \int_{r_i}^{r_o} r^2 \, dr = \frac{2}{3} \frac{\pi \mu \, p}{\sin\theta} \cdot \left(r_o^3 - r_i^3 \right)$$

$$T_f = \frac{2}{3} \cdot \frac{\mu}{\sin\theta} \cdot F_a \cdot \frac{r_o^3 - r_i^3}{r_o^2 - r_i^2}$$

$$T_{f_{UP}} = \frac{\mu}{\sin\theta} \cdot F_a \cdot r_m$$

UWD Case:

$$F_a = 2\pi K' \cdot \left(r_o - r_i \right)$$ (see plate clutches)

$$T_f = \frac{\pi \mu}{\sin\theta} \cdot K' \cdot \left(r_o^2 - r_i^2 \right)$$

$$T_{f_{UW}} = \frac{\mu}{\sin\theta} \cdot F_a \cdot \left(\frac{r_o + r_i}{2} \right)$$

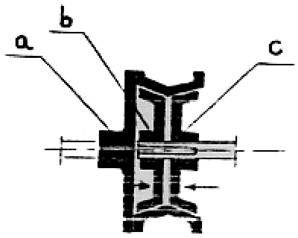
$Wear = k\,p\,V$, $V = \omega r$

$Wear = K\,p\,r$

$p = \frac{K'}{r}$

$F_a = 2\int_{r_i}^{r_o} \pi \, p \, r \, dr$

$= 2\pi K' (r_o - r_i)$



Design Considerations:

Angle of cone:

With the increase of θ, P decreases

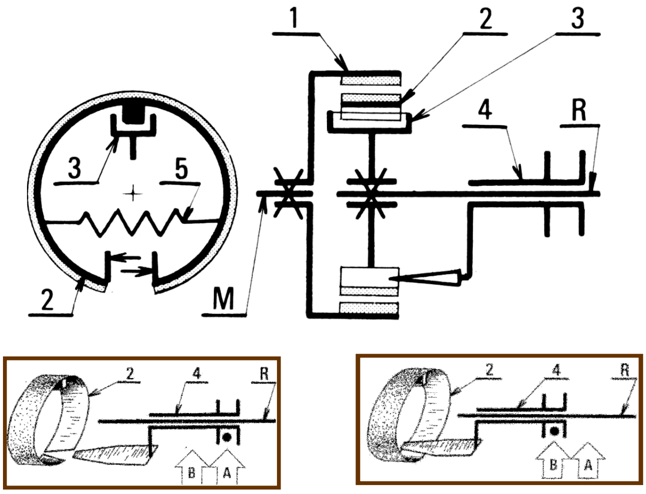
θ : 12.5° SAE

$d_m / b_{conical}$

Double Cone Clutch

With double cone clutches

Cylindrical Clutch



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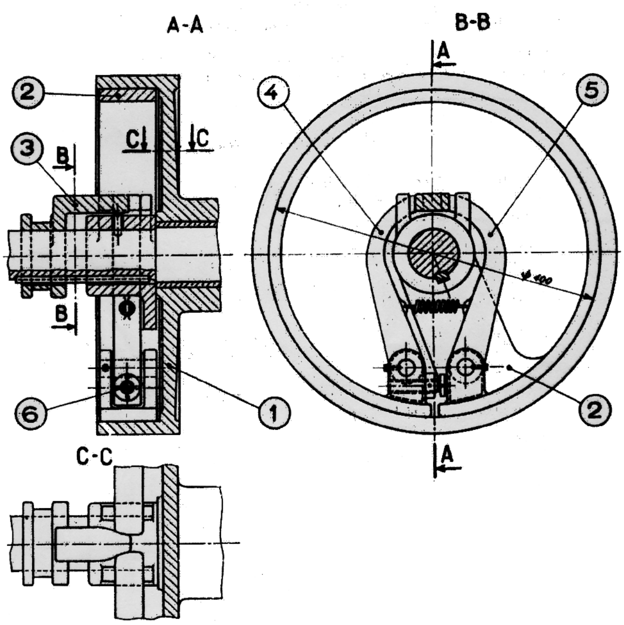
Cylindrical Clutch



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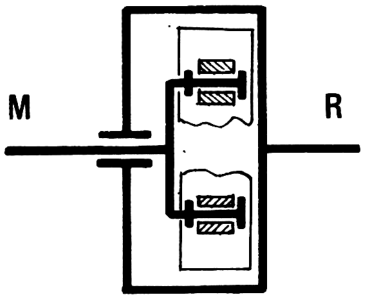
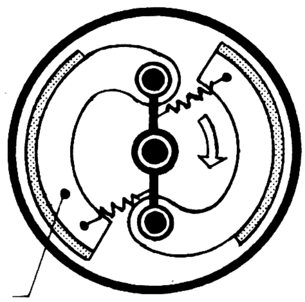
Centrifugal Clutch





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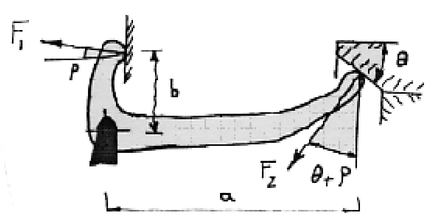
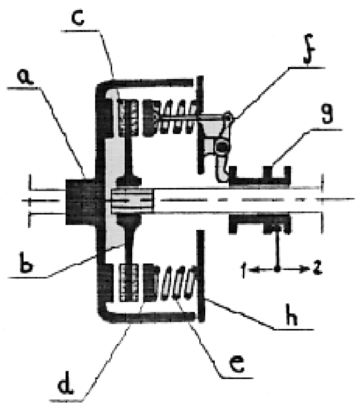
METHOD OF CLUTCH OPERATION

MECHANICAL





Bell crank lever,
ρ : friction angle

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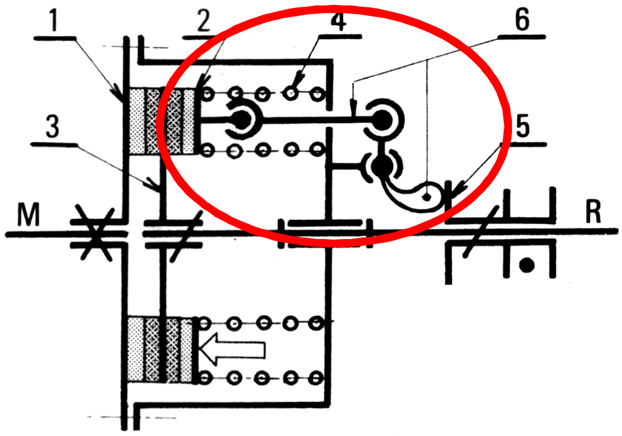
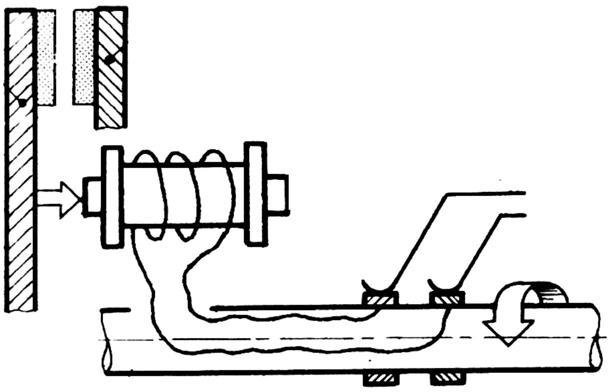
Mechanical Force Generation



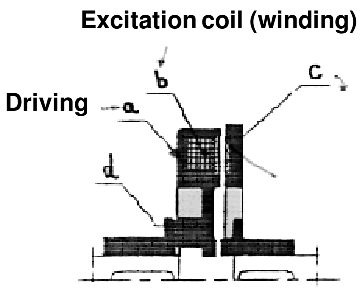
Electro-Magnetic Force Generation



Electro-Magnetic Clutch

Electromagnetic clutches are employed to advantage

Engagement can be as gradual as desired, within the capacity of the temperature range of the friction material used.



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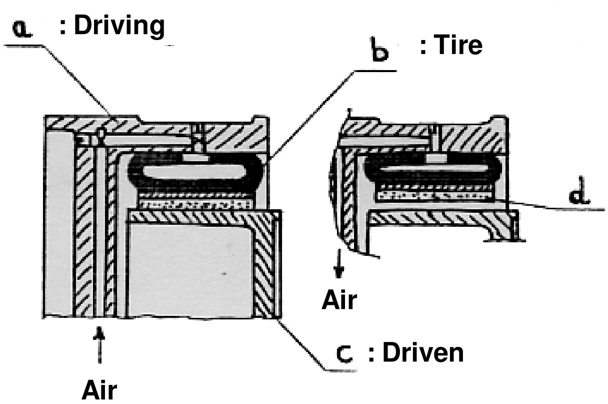
Pneumatic Force Generation



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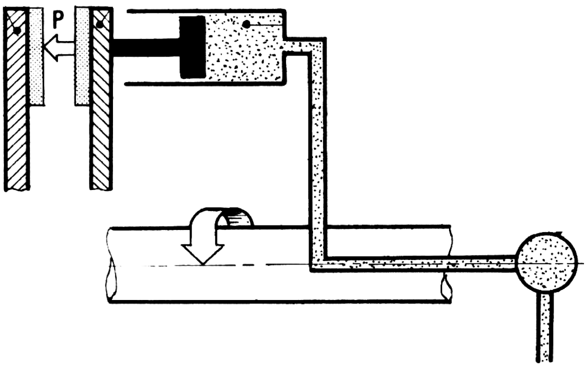
Hydraulic Force Generation



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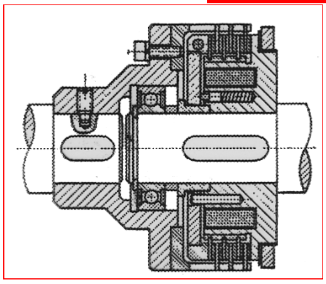
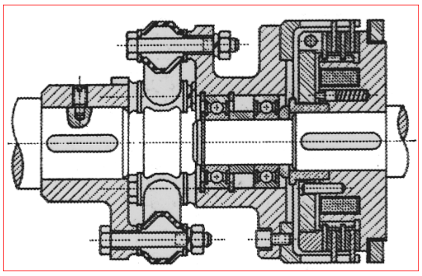
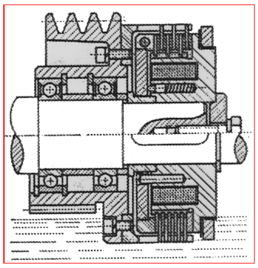
Clutch Designs







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Slipping Clutches

Such clutches protect machines against overload.

FRICTION SLIPPING CLUTCH

Usually slip begins if the load exceeds for which the shafts and other parts are designed.

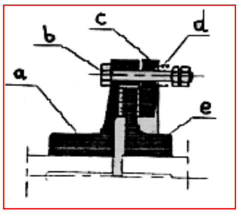
Number of pairs of surfaces in contact:

D_o / D_i =

Number of springs:

6 for small clutches

16 for larger clutches



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Slipping Clutches

SHEARING PIN CLUTCH

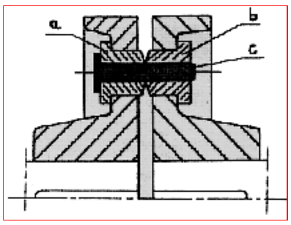
When the torque exceeds a predetermined value

$T = n\,\pi\, d^2/4 \,.\, \tau_u . r$

n :

τ_u : ultimate

d : pin diameter



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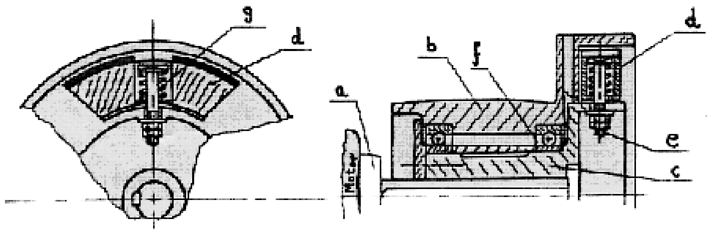
CENTRIFUGAL CLUTCHES



These clutches, usually automatic in action, are numerous in general engineering and are normal equipment in the simple squirrel cage induction motor, overcoming its poor starting characteristics by allowing the motor to take up its load after the rotor has gained speed.
In other words a high initial torque output of the driving motor, or prime mover, is not required.